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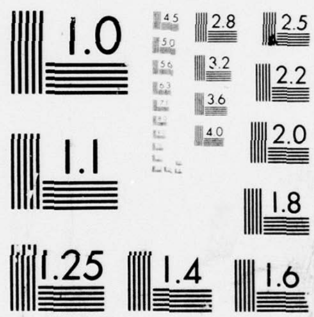

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THE RESPONSE OF THE SEA BREEZE CIRCULATION TO SEA SURFACE TEMPERATURE PERTURBATIONS GENERATED BY OCEAN THERMAL POWER PLANTS

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R. Michael Clancy
Glyn O. Roberts

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Ocean Thermal Power Plants (OTPP's) will cool the upper layer of the ocean and reduce the sea surface temperature (SST). If this SST perturbation extends near shore, it could possibly affect the sea breeze circulation. In this brief report we give a short description of the sea breeze circulation and estimate its response to OTPP activity. These estimates are based on observations rather than models.

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We conclude that detailed model studies of OTEC impacts on the sea breeze are not appropriate, for three reasons. First, our estimates of impacts of order 10%, associated with large scale OTEC implementation, appear sufficient. Secondly, the state-of-the-art in sea breeze modeling and in the parameterization of boundary-layer mixing and of cumulus convection is probably not yet adequate for such model studies. Thirdly, the impacts are small, and affect only a limited area; thus significant expenditures are hard to justify.

We have not ruled out the possibility of significant climate impacts associated with the lowering of the sea surface temperature by OTEC. This question is beyond our present scope.

TABLE OF CONTENTS

Section 1

INTRODUCTION

Ocean Thermal Power Plants (OTPP's) will cool the upper layer of the ocean and reduce the sea surface temperature (SST). If this SST perturbation extends near shore, it could possibly affect the sea breeze circulation. In this brief report we give a short description of the sea breeze circulation and estimate its response to OTPP activity. These estimates are based on observations rather than models.

We conclude that detailed model studies of OTEC impacts on the sea breeze are not appropriate, for three reasons. First, our estimates of impacts of order 10%, associated with large scale OTEC implementation, appear sufficient. Secondly, the state-of-the-art in sea breeze modeling and in the parameterization of boundary-layer mixing and of cumulus convection is probably not yet adequate for such model studies. Thirdly, the impacts are small, and affect only a limited area; thus significant expenditures are hard to justify.

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Section 2

THE SEA BREEZE CIRCULATION

Available potential energy is generated locally when the atmosphere is subjected to differential heating cuased by the daytime land-sea contrast in surface temperature at a sea coast. The sea breeze circulation converts the available potential energy to kinetic energy, with warm air rising over the land and cooler air descending over the sea. The land-sea thermal contrast is often reversed at night and a land breeze forms with a sense of circulation opposite to that of the sea breeze. The land breeze is usually weaker than the sea breeze.

The horizontal extent of the sea breeze circulating is large enough that the earth's rotation is important. Consequently, the sea breeze wind vector usually turns clockwise with time in the Northern Hemisphere. Thus, as the sea breeze begins in the morning, it is almost perpendicular to the coast, while by its mid-afternoon peak it has been deflected typically 45^{o} to the right.

The sea breeze phenomenon is naturally dependent on the synoptic (large-scale) distribution of wind, temperature, and moisture. It is obscured or non-existent when there is a strong synoptic wind component normal to the coast. We are concerned particularly with conditions at the Gulf of Mexico or the Atlantic coast because the California coast does not provide a thermal resource adequate for OTEC. On the Gulf coast, land topography is not significant. The sea breeze is strongest in early summer, when the land-sea temperature difference can be as high as 20^{o}C.

When the prevailing large-scale wind is weak (less than 2m/sec) and approximately parallel to the coast, the sea breeze circulation develops first in the immediate vicinity of the coast and then grows both horizontally (seaward as well as landward) and vertically. The zone of low-level convergence which separates the cool air (advected landward by the sea breeze) from the warmer air inland is often (observed to be) sharp and is referred to as the "sea breeze front". The upward motion in the sea breeze front often gives rise to cumulus clouds (Wallington, 1960). The landward propagation of the front is a highly nonlinear phenomenon.

The following table gives typical magnitudes for the observed sea breeze in the coastal area of the Gulf of Mexico. As remarked earlier, the phenomenon is dependent on a number of synoptic factors, and these values can be regarded only as characteristic. For each land-sea temperature difference, the table gives the maximum surface wind, and the landward and seaward extents of the sea breeze. The last two entries are for the land breeze, with a negative temperature difference. Cumulus convection is most important for the larger temperature differences.

TABLE 1. TYPICAL SEA BREEZE MAGNITUDES AS A FUNCTION OF LAND-SEA TEMPERATURE DIFFERENCE

Temperature Difference $\Delta T\,^{o}C$		20	15	10	5	-5	-10
Maximum Wind	m/s	6.0	2.7	1.5	0.6	0.5	1.0
Landward Extent	km	150	100	50	15	8	20
Seaward Extent	km	50	35	25	20	12	35

Section 3

SEA BREEZE MODELS

Since nonlinearities are important in the sea breeze circulation, it has most often been studied with numerical rather than analytical models. Estoque (1961) was probably the first to undertake a numerical investigation of the sea breeze and since then such studies have proliferated. Most of these studies have been two-dimensional, although the work of Pielkl (1974), who studied the sea breeze over South Florida with a three-dimensional model, is a notable exception.

The various numerical models give qualitative agreement with the observations, and with the numerical values summarized in Table 1. The main features of the sea breeze, including the surface wind speed and direction and its variation through the day, and the advancing sea-breeze front, are qualitatively reproduced in at least some of the models. However, precise quantitative agreement has not been obtained.

The existing sea breeze models have room for improvement in two areas: parameterization of subgrid-scale heat, moisture, and momentum fluxes in the boundary layer and the parameterization of cumulus convection in the ascending branch of the sea breeze cell (see Wallington, 1960). Although steady progress has been made on the first problem over the years, very little progress has been made on the second.

Section 4

SEA BREEZE MODIFICATION DUE TO OTEC

The removal of heat by OTEC from the surface layers of the tropical ocean will result in a slight lowering of the mean sea surface temperature, as discussed by Piacsek, et al. (1976), Martin and Roberts (1977), and Roberts, et al. (1978). This is so whether separate or mixed discharges are used. The heat balance is maintained by a reduction in the surface heat loss (particularly due to evaporation) associated with the reduction in surface temperature. Large-scale OTEC implementation in the Gulf of Mexico could result in a reduction of the mean sea surface temperature by as much as $1^{\circ}C$.

The effect on the regional climate of such a change is beyond the scope of this report. Similar climate studies have been performed by others, using numerical models of the general circulation of the atmosphere, with inconclusive results. Here we are concerned only with the modification of the sea breeze due to the altered land-sea temperature difference, assuming fixed large-scale synoptic conditions. Thus we do not address the larger question of regional climate impacts.

The impact of an altered sea surface temperature on the sea breeze can be estimated from the observational data base, on the assumption that the main factor in determining the magnitude and extent of the sea breeze is the land-sea temperature difference. As discussed above in Section 2, the other factors (synoptic atmosphere conditions

and topography) are less significant, and can be regarded as fixed. The lowering of the sea surface temperature will result in a slight increase in the magnitude and extent for the sea breeze, and a slight decrease for the night land breeze.

A quantitative estimate for the modification can be made from the observational data summarized in Table 1. The strongest sea breeze effect is associated with a temperature difference of 20°C, occurring at mid-afternoon in the early summer around the Gulf of Mexico. Reducing the sea surface temperature by 1°C would increase this difference by 5%, and from the table, would increase the magnitude and extent of the sea breeze by about 10%.

For weaker natural temperature differences, the percentage changes in the land-sea temperature difference and in the associated magnitude and extent of the sea breeze will be larger. However, Table 1 demonstrates that the magnitudes of the changes will be smaller.

Our estimates of the modified sea breeze associated with a reduction of the coastal sea surface temperature by 1°C, with fixed synoptic conditions, are given in Table 2. These estimates are based on interpolation from Table 1. The temperature reduction by 1°C should be regarded as an extreme figure, associated with large-scale OTEC implementation in a limited area. It should be noted from the table that while the sea breeze is increased, the weaker night land breeze is decreased.

TABLE 2. ESTIMATE OF SEA BREEZE INCREASE DUE TO A 1°C LOWERING OF THE SEA SURFACE TEMPERATURE

Natural ΔT	°C	20	15	10	5	-5	-10
Increased ΔT	°C	21	16	11	6	-4	-9
Maximum Wind	m/s	6.8	3.0	1.7	0.7	0.4	0.8
Increase	m/s	0.8	0.3	0.2	0.1	-0.1	-0.2
Landward Extent	km	160	110	60	30	6	16
Increase	km	10	10	10	5	-2	-4
Seaward Extent	km	53	37	27	11	10	32
Increase	km	3	2	2	1	-2	-3

Section 5

CONCLUSIONS AND RECOMMENDATIONS

Our estimates of OTEC impacts on the sea breeze are given in Table 2. Impacts of smaller or larger reductions in the coastsl sea surface temperature would be roughly in proportion. These estimates are based on sea breeze observations, assuming the land-sea temperature difference is the main determining factor.

We do not recommend detailed numerical model studies of the sea breeze and the OTEC modification. There are three reasons for this. First, our estimates of the modification are probably adequate, and refining of these estimates (including the effects of synoptic conditions) could be done using only the observational data base. Secondly, the existing numerical models and the parameterization of boundary-layer mixing and cumulus convection are inadequate for a full quantitative study in two or three dimensions. Thirdly, our estimates imply that the modification is small, and affects only a limited area, even for large-scale OTEC implementation. For surface cooling by $1^{o}C$, the largest wind increase estimate is from 6 m/s to 6.8 m/s, for a natural land-sea temperature difference of $20^{o}C$.

We recommend that further consideration be given to the possibility of significant regional climate impacts associated with the lowering of the sea surface temperature by OTEC. There are various methods of approaching this problem; some involve statistical correlations of observations and some involve modeling. This issue is beyond our present scope.

Section 6

REFERENCES

1. Estoque, M.A., 1961, "A Theoretical Investigation of the Sea Breeze", Quart. J. Roy. Meteor. Soc., 87, 136-146.

2. Martin, P.J. and G.O. Roberts, 1977, "An Estimate of the Impact of OTEC Operation on the Vertical Distribution of Heat in the Gulf of Mexico", Proceedings of the Fourth Annual Conference on OTEC, pp. IV-26-34.

3. Neumann, R.J., and B.A. Mahrer, 1971, "A Theoretical Study of the Land and Sea Breeze Circulation", J. Atmos. Sci., 28, 532-542.

4. Physick, W., 1976, "A Numerical Model of the Sea Breeze Phenomenon Over a Lake or Gulf", J. Atmos. Sci., 33, 2107-2135.

5. Piacsek, S.A., P.J. Martin, J. Toomre, and G.O. Roberts, 1976, "Recirculation and Thermocline Perturbations from Ocean Thermal Power Plants", NRL-GFD/OTEC 2-76, 25 pp.

6. Pielke, R., 1974, "A Three-Dimensional Numerical Model of the Sea Breeze Over South Florida" , Mon. Wea. Rev., 102, 115-139.

7. Roberts, G.O., W.J. Grabowski and P.J. Martin, 1978, "OTEC Impact on the Mean Thermal Profile in the Gulf of Mexico", to appear.

8. Wallington, C.E., 1960, "Convection at the Sea Breeze Front", In Cumulus Dynamics, Oxford, Pergamon Press, 119-125.